FIRE RETARDANT WAFER CARRIER

RELATED APPLICATIONS

This application claims the benefit of U.S. Utility Patent Application Serial No. 10/190,355 and U.S. Provisional Patent Application Serial No. 60/394,219, each of which is hereby fully incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to wafer carriers. More particularly it relates to fire retardant wafer carriers.

BACKGROUND OF THE INVENTION

Processing of semi-conductor wafers into finished electronic components typically requires many processing steps where the wafers must be handled and processed. The wafers are very valuable, and are extremely delicate and easily damaged by physical and electrical shocks. In addition, successful higher yield processing requires the utmost in cleanliness, freedom from particulates and other contaminants. As a result, specialized containers or carriers have been developed for use during processing, handling and transport of wafers. These containers protect the wafers from physical and electrical hazards, and are sealable to protect the wafers from contaminants. Additionally, since the processing of wafer disks is generally automated, it is necessary for disks to be precisely positioned relative to the processing equipment for the robotic removal and insertion of the wafers. A second purpose of a wafer carrier is to securely hold the wafer disks during transport.

Carriers are generally configured to axially arrange the wafers or disks in article supports in the form of shelves or slots, and to support the wafers or disks by or near their peripheral edges. The wafers or disks are conventionally removable from the carriers in a radial direction upwardly or laterally. Carriers may have supplemental top covers, bottom covers, or enclosures to enclose the wafers or disks. Examples of specialized carriers and methods for forming them are disclosed in U.S. Patent Nos. 6,439,984; 6,428,729; 6,039,186; 6,010,008; 5,485,094; 5,944,194; 4,815,601; 5,482,161; 6,070,730; 5,711,427; 5,642,813; and 3,926,305, all assigned to the owner of the present invention, and all of which are hereby fully incorporated herein by reference. For the purposes of the present application, the term "carrier" includes, but is not limited to: semiconductor wafer carriers such as H-bar wafer carriers, Front Opening Unified Pods (FOUPs), and Standard Mechanical Interface Pods (SMIFs); reticle carriers; WIP boxes, and other carriers used in the micro-electronic industry for storing, transporting, fabricating, and generally holding small electronic components such as hard drive disks and other miscellaneous mechanical devices.

The semiconductor industry is in the process of evolving fabrication facilities to use wafers having a diameter of 300 mm. The wafer carriers used for 300 mm wafers are normally configured as a Front Opening Unified Pod (FOUP). Examples of FOUP wafer carriers are disclosed in U.S. Patent Nos. 6,082,540, 6,206,196, 6,216,874 and 6,267,245, each commonly owned by the assignee of the present invention, and each of which is fully incorporated herein by reference.

There are a number of material characteristics which are useful and advantageous for wafer carriers depending on the type of carrier and the particular part of the carrier at issue.

Carrier materials should also have minimal outgassing of volatile components as these may leave films which also constitute a contaminant which can damage wafers and disks. The carrier materials must have adequate dimensional stability, that is rigidity, when the carrier is loaded. Dimensional stability is necessary to prevent damage to the wafers or disks and to minimize movement of the wafers or disks within the carrier. The tolerances of the slots holding wafers and disks are typically quite small and any deformation of the carrier can directly damage the highly brittle wafers or increase the abrasion and thus the particle generation when the wafers or disks are moved into, out of, or within the carrier. Dimensional stability is also extremely important when the carrier is loaded in some direction such as when the carriers are stacked during shipment or when the carriers integrate with processing equipment. The carrier material should also maintain its integrity under elevated temperatures which may be encountered during storage or cleaning. U.S. Pat. No. 5,780,127 discusses various characteristics of plastics which are pertinent to the suitability of materials for wafer carriers, and is incorporated herein by reference.

Visibility of wafers within closed containers is highly desirable and may be required by end users. Polycarbonate material is extensively used for the enclosure portion of carriers, because of its transparency, ease of molding, and favorable abrasion resistance, heat resistance, chemical resistance, outgassing containment, rigidity characteristics, creep reduction, fluid absorption containment, UV protection, and other performance characteristics. In addition, polycarbonate is typically dramatically less expensive than other polymers that are suitable for use in carriers, such as polyetheretherketone (PEEK).

For these reasons, conventional practices typically include constructing an entire carrier enclosure of polycarbonate material. While polycarbonate has the many favorable characteristics outlined above, however, it is also a relatively flammable material that readily propagates flame. Free burn testing involving an array of only four polycarbonate FOUP wafer carriers has shown peak heat release rates of more than 1 MW. Because as many as 5,000 to 10,000 FOUP wafer carriers may be stored in a single semiconductor processing facility, there is a non-trivial risk of fire in such facilities associated with polycarbonate wafer carriers. Not only does fire in a semiconductor processing facility pose a risk of significant property loss and hazards to the life safety of occupants in the facility, even a small fire may cause extreme disruption to the semiconductor production process due to contamination from airborne particulates and combustion products. Thus, while there have been no known fire losses to date from a wafer carrier fire, the potentiality and possible consequences of such an event make improvements to fire safety associated with wafer carriers highly desirable.

Wafer carriers are often stored in multi-tier storage racks known as "stockers". In a stocker, carriers are stored side-by-side in vertically stacked tiers. These stockers are typically arranged in opposing fashion across an aisle, from which they may be accessed by robotic equipment. Each stocker may be multi-floors high and may contain hundreds of carriers. While vertical stacking offers an efficient means of storing many types of devices and materials, including wafer carriers, it is well known that stacked arrangements of flammable materials present a heightened fire protection concern. This is due to the general tendency of fire to propagate more readily vertically through buoyant motion of pyrolysis products. In addition, fixed fire sprinkler protection covering all areas of stacked material is often very difficult and

expensive to achieve. As a result, in order to minimize the size and rate of fire growth in a vertical storage arrangement, one important fire protection strategy is to retard, or preferably even prevent, the vertical propagation of fire from material in one tier of storage to next tier that is immediately vertically adjacent. To the extent that propagation of a fire beyond the area of ignition can be slowed, more time is provided for detection and suppression of the fire in its incipient stages, thus minimizing damage and process disruption.

Two important variables that can have a significant effect on fire propagation in vertical storage are the geometry of the stored items and the flame propagation characteristics of the material composition of the items. In common fire protection engineering practice, these variables may sometimes be altered so as to obtain an optimal result from a fire protection standpoint. Wafer carriers, however, present a unique challenge in this regard in that the requirements of the semiconductor industry for wafer carriers are very stringent and process critical. For instance, in a wafer carrier, there may be over 200 precise dimensions required to hold wafers in place repeatably, and there are also stringent material standards for mechanical strength, structural integrity, and chemical stability of the materials used in the carrier as mentioned above. Any modifications made to carriers for the purposes of fire safety must not compromise these standards. Because of these difficulties, previous efforts to improve the fire safety of wafer carriers, both existing and new, have proceeded slowly and have not produced significant changes in wafer carrier design to date.

What is still needed in the industry is a relatively low cost carrier having the needed transparency, ease of molding, favorable abrasion resistance, heat resistance, chemical

resistance, outgassing containment, rigidity, creep reduction, fluid absorption containment, UV protection, and fire resistance characteristics.

SUMMARY OF THE INVENTION

The present invention substantially meets the needs of the industry for a relatively low cost carrier having performance characteristics sufficient to meet the needs of the semiconductor processing industry while also having significantly improved fire resistance charactistics. Further, the present invention meets the need for a wafer carrier that is resistant to the vertical propagation of fire, especially when multiple wafer carriers are stored in a vertical stocker arrangement. In addition, the present invention permits the use of less-expensive, more easily formable, polycarbonate plastic for the carrier, while still offering resistance to the vertical propagation of fire.

In the invention, a carrier includes an enclosure portion formed substantially from polycarbonate plastic. Selected portions of the enclosure have an outer surface portion formed substantially from a plastic material having a Fire Propagation Index of not greater than 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$. Suitable plastic materials include polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene.

An advantage of the invention is that a carrier enclosure may have significant portions formed from relatively low-cost, easily formable, transparent polycarbonate. Much higher cost fire resistive polymer materials may be selectively positioned on the enclosure where necessary to impact spread of fire on the carrier and to other adjacent carriers.

Another advantage of the invention is that the fire retardancy of existing polycarbonate carriers may be improved.

Accordingly, a carrier for articles according to the invention includes an enclosure having an outer surface and an article support in the enclosure. The enclosure has a first portion formed substantially from polycarbonate plastic, and a second portion formed from a fire retardant plastic material having a flame propagation index of not greater than 9.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$. The second portion forms at least a portion of the outer surface of the enclosure, whereby the outer surface portion is relatively retardant to vertical propagation of flame. The fire retardant plastic material may be selected from the group of plastic materials consisting of polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene.

The invention may also include a wafer carrier having an enclosure portion formed substantially from polycarbonate plastic having at least a top, a bottom, a pair of opposing sides, a back, and an open front. The carrier further includes a door to close the open front, wherein the door has an outer surface portion formed substantially from a plastic material selected from the group of plastic materials consisting of polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene, and wherein the plastic material has a Fire Propagation Index of not greater than 9.0 (m/s $^{1/2}$)(kW/m)$^{-2/3;}$.

Additional objects, advantages, and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects

and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation view of a plurality of wafer carriers arrayed in stockers;

FIG. 2 is a perspective view of a wafer carrier;

FIG. 3 is an elevation view of a wafer carrier door according to a preferred embodiment of the present invention;

FIG. 4 is a perspective, partially exploded view of a wafer carrier and door according to the present invention;

FIG. 5 is a perspective, partially exploded view of an alternative embodiment of a carrier according to the invention;

FIG. 5a is a cross-sectional view of one embodiment of the invention taken at section 5a-5a of Figure 5;

FIG. 5b is a cross-sectional view of an alternative embodiment of the invention taken at section 5b-5b of Figure 5; and

FIG. 6 is a perspective view of a shipping box according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The accompanying Figures depict embodiments of the wafer container of the present invention, and features and components thereof. Any references to front and back, right and left,

top and bottom, upper and lower, and horizontal and vertical are intended for convenience of description, not to limit the present invention or its components to any one positional or spacial orientation. Any dimensions specified in the attached Figures and this specification may vary with a potential design and the intended use of an embodiment of the invention without departing from the scope of the invention.

In Figure 1, there is depicted a plurality of FOUP wafer carriers 100 arrayed in typical vertical stockers 150. A typical semiconductor processing facility may have multiple rows of stockers 150 arranged in parallel fashion with aisles 180 between the rows as shown. Robotic handling equipment may be used in aisles 180 to transfer wafer carriers 100 to and from stockers 150. Within each stocker 150, wafer carriers 100 are supported side-by-side by horizontal supports 160, forming vertically stacked tiers 162 of wafer carriers 100. Wafer carriers 100 are normally arranged in stockers 150 so that the door of the carrier faces outward into aisle 180.

Referring to FIG. 2, a typical FOUP wafer container 100 as used in the art has an enclosure portion 102, constructed of polycarbonate plastic, and having a top 104, a bottom 106, a pair of opposing sides 108 and 110, and a back 112. A door 114 closes the open front 116 of the enclosure portion 102, fitting into door recess 118. Wafer supports 122 are provided to support semi-conductor wafers within the enclosure. Kinematic coupling 124, mounted to the exterior surface of enclosure bottom 106 is provided to facilitate automated handling of the container during use and to provide a reference datum for locating the wafers in the housing during processing. Robotic lifting flange 126 is mounted on the exterior surface of enclosure top 104 and is provided to facilitate automated handling and transport of container 100 during use.

As may be seen from reference now to FIGs. 1 and 2, vertical propagation of fire within stockers 150 may be retarded between tiers 162 at the sides 108, 110 and back 112 of wafer carriers 100 by providing solid portions in horizontal supports 160, blocking any vertical openings between tiers. At the front, however, doors 114 are vertically aligned, forming a pathway for vertical propagation of fire between tiers 162.

It is known in the art to classify materials according to the relative propensity of the materials to propagate fire. One such classification, considered particularly indicative of the fire propagation behavior of materials under highly radiative flame conditions prevalent in large scale fires, uses a Fire Propagation Index (FPI) value that is determined for the material. To determine the FPI of a material, the material is tested according to methods well known in the art to determine a peak chemical heat release rate per unit width (Q'_{ch}), and a Thermal Response Parameter (*TRP*), which is calculated according to the relation:

$$TRP = \Delta T_{ig}\sqrt{k\rho c_p}$$

where ΔT_{ig} is the ignition temperature of the material above ambient in K°, k is the material thermal conductivity in kW/m-K°, ρ is the material density in g/m^3, and c_p is the material specific heat in kJ/g-K°. The FPI may then be calculated according to the relation:

$$FPI = 1000\left(\frac{(0.42\, Q'_{ch})^{1/3}}{TRP}\right)$$

Materials may be generally classified according to their FPI value. Materials having an FPI of under 7.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$ are classified as Group N-1 "Non-Propagating" materials, those having an FPI of less than 10.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$ but at least 7.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$ are

classified as Group D-1 "Decelerating" materials, those having an FPI of between 10.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$ and 20.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$ are Group 2 "Non-Accelerating Propagation" materials and those having an FPI of over 20.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$ are Group 3 "Accelerating Propagation" materials.

Polycarbonate plastic, as is commonly used for the enclosure and doors of wafer carriers, normally has a Fire Propagation Index (FPI) of greater than about 10.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$, which classifies it as a Group 2 or Group 3 fire propagating material. In accordance with the invention, at least the outer surface portion 130 of door 114 of each wafer carrier is formed substantially from a Group N-1 or Group D-1 fire retardant plastic material that has an FPI of 9.0 (m/s $^{1/2}$)(kW/m)$^{-2/3}$ or less. Although any fire retardant plastic material having an appropriate FPI may be suitable for the purpose, plastics that are known to be acceptable for use in wafer carriers and that have the appropriate FPI are polyimide (PI), polyether imide (PEI), polyamide imide (PAI), polyketone (PK), polyetherketone (PEK), polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyether sulphone (PES), and polytetrafluoroethylene (PTFE). The currently most preferred material is PEI having an FPI from between about 8.1 (m/s $^{1/2}$)(kW/m)$^{-2/3}$ to about 8.6(m/s $^{1/2}$)(kW/m)$^{-2/3}$, such as for example, Ultem 1000 made by GE Plastics, Inc. of Pittsfield, Massachusetts.

In a preferred embodiment of the invention, at least outer surface portion 130 of door 114 is formed from PEI material. It is currently most preferred that the thickness of outer surface portion 130 formed from the fire retardant plastic material be at least the typical thickness of enclosure portion 102, which is generally about 0.3 mm. It is currently most preferred that outer surface portion 130 is the exterior panel 132 of door 114 alone as shown in FIG. 2, but may also

be a separate fire-retardant layer 134 laid over exterior panel 132 of door 114 as shown in FIG. 3. Such a fire retardant layer 134 may be overmolded on exterior panel 132, forming a thermal as well as a mechanical bond with exterior panel 132, or may be a separate shield panel 136 as shown in FIG. 4, attached by any suitable method, including adhesives or mechanical fasteners. As an alternative, shield panel 136 may have structures allowing it to removably "snap" on and off suitable receiving structures on door 114.

Alternatively, the outer fire resistant layer can be a thin film that has been insert molded on the forward facing surface of the front door. A suitable method of film insert molding is disclosed in U.S. Patent Application Serial Number 10/304,775, entitled "SEMICONDUCTOR COMPONENT HANDLING DEVICE HAVING A PERFORMANCE FILM", commonly owned by the owners of the present invention and hereby fully incorporated herein by reference. Co-pending U.S. Patent Application 09/317,989 owned by the present applicant discloses the use of overmolding to manufacture carriers and components and is also herein incorporated by reference. Other portions of door 114, such as the chassis 140, latching components, and inner surface 142 may also be formed from the same fire retardant material used for outer surface portion 130, and this may serve to improve the overall fire retardancy of wafer carrier 100.

Existing wafer carriers with polycarbonate outer surfaces may be retrofitted using the apparatus and methods of the present invention. Such a retrofit may be accomplished in the case of a FOUP by replacing the polycarbonate door with a door 114 manufactured according to the present invention, or by overlaying exterior panel 132 with shield panel 136 as described above. Such a shield panel may be a flexible sheet material suitably adhered to existing door structure.

It will be appreciated that the materials and methods of the present invention could be applied to other surfaces on a FOUP and to any other type of carrier. Thus, for example, if fire retardant surfaces are made necessary by openings in horizontal supports 162 of stocker 150, sides 108, 110 and/or back 112 of a FOUP could be made with an outer surface of fire retardant plastic having the appropriate FPI value as described hereinabove.

As depicted in Figure 5 for example, a SMIF pod carrier 200 has a base portion 202 and a cover portion 220, with sides 222, front 224, and back 228. Cover portion 220 engages base portion 202 at recessed region 282, with the bottom periphery of cover portion 220 fitting aroung and covering periphery 280 of base 202. A article support in the form of H-bar wafer carrier 260 having wafer shelves 262 is engaged with base 202 inside the enclosure. In accordance with the invention, selected portions 230 of the outer surface 232 of cover portion 220 may be made from a polymer material having an FPI of 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$ or less. At selected portions 230, cover portion 220 may be entirely formed from the fire resistant material as depicted in Figure 5a. In this embodiment, a first portion 234 of the enclosure is formed from polycarbonate, and a second portion 236 is formed from the fire retardant polymer material. The first and second portions may be molded together using conventional molding techniques. Alternatively, a layer of the fire resistant material 238 may be applied at selected portions 230 over a layer 240 of lower cost polymer such as polycarbonate as depicted in Figure 5b, by any suitable method, such as film insert molding, overmolding, or welding as described above. Again, it is anticipated that layer 238 should be at least about 0.3 mm in thickness for best fire retardancy results. Alternatively, separate shield panels may be affixed over a polycarbonate cover portion 220 by welding, fasteners, or adhesive as described above.

In a shipping container 300 embodiment as depicted in Figure 6, cover portion 302 may have selected portions 304 of the outer surface 306 made from a polymer material having an FPI of 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$ or less. Again at selected portions 304, cover portion 302 may be entirely formed from the fire resistant material or a layer of the fire resistant material may be applied over a layer of lower cost polymer such as polycarbonate by film insert molding, overmolding, or welding as described above. It is anticipated that it may be especially advantageous to form overhanging lip portions 310 from fire retardant plastic material. Hot pyrolysis products from a burning base portion 312 of the container 300 will be deflected outward by overhanging lip portions 310, away from vertical surfaces 314, thereby inhibiting vertical propagation of fire. In addition, as base portion 312 burns and melts, cover portion 302 may settle downward, tending to suppress the fire underneath.

Although the description above contains many specificities, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of the invention. Thus, the scope of the invention should be determined by the appended claims and their legal equivalents, rather than by the examples given.